

1.26 μ m GaInNAsSb-SQW Lasers Grown by Gas-Source MBE

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Abstract: Long wavelength-GaInNAsSb SQW lasers that include small amount of Sb were successfully grown by gas-source molecular beam epitaxy (GSMBE). We confirmed that Sb reacts in highly strained GaInNAs/GaAs system like a surfactant, which increase the critical thickness at which the growth mode changes from the 2-dimentional (2-D) growth to the 3-dimentional (3-D) growth. The GaInNAsSb lasers oscillated under CW operation at 1.258 μ m at room temperature. The low CW threshold current of 12.4mA and high characteristic temperature (T_0) of 157K were obtained for GaInNAsSb lasers, which is the best result for GaInNAs-based narrow stripe lasers.

Introduction: Long wavelength lasers emitting at 1.2~1.3 μ m grown on GaAs substrates have been attracting much interest. The large T_0 of 127-274K [1-3], which are much larger than conventional long-wavelength GaInAsP/InP system, have been reported in GaInNAs lasers. Therefore, pertier-free system with low cost for access network can be realized by using GaInNAs system. However, the crystalline of GaInNAs is still poor for laser applications, and many methods to improve the quality is now undertaken, where the usage of surfactant [4, 5] is thought to be one solution.

In this paper, we investigated highly strained GaInNAs SQW lasers that include a small amount of Sb like a surfactant on the GaAs substrates to improve the crystalline-quality by gas-source molecular-beam epitaxy (GSMBE) growth. We report the high performance CW lasing characteristics of 1.26 μ m-GaInNAsSb SQW lasers (I_{th} =12.4mA @25°C, T_0 =157K(@25-85°C).

Fabrications and Results: Highly strained Ga_{0.61}In_{0.39}N_{1-y1-y2}As_{y1}Sb_{y2}/GaAs SQW lasers were grown on n-GaAs substrates by GSMBE in which the N source is N radical generated by RF plasma cell, and the other group V were supplied by AsH₃ and PH₃, and In, Ga, Sb were supplied by solid source. The lasers consisted of n-, p-GaInP cladding, a highly strained SQW active layer (7.3nm-thick), and 130nm thick GaAs SCH layers located on both sides of SQW layer as shown in figure 1. To recover the crystalline quality of GaInNAsSb SQW, the lasers were annealed after the growth at 650°C for 10 minutes in the atmosphere of N₂ flow. By adding Sb during the growth of the well layer, we investigated the photoluminescence (PL) characteristic dependence on the flux of Sb as shown in figure 2. We can see that Sb is very effective to improve the crystalline quality in the highly strained GaInNAs/GaAs SQW and that PL intensity increase most efficiently with the Sb flux of 1x10⁻⁶torr, where the composition of Sb can be estimated as 1.6% from the evaluation of GaAsSb bulk layer. The wavelength of as-grown Ga_{0.61}In_{0.39}As_{0.984}Sb_{0.016} and as-grown Ga_{0.61}In_{0.39}N_{1-y-0.016}As_ySb_{0.016} were 1.19 μ m and 1.27 μ m, respectively. We estimated N composition as 0.44% from the wavelength shift of 80nm. The FWHM of GaInNAsSb SQW was as narrow as 23meV, which is almost the same value as GaInAsSb SQW lasers (19meV). To investigate the crystalline characteristics of GaInNAsSb SQW laser further, we observed the transmission electron microscopy (TEM) for the film with variety of Sb amount. Figure 3 show TEM images for GaInNAsSb-SQW lasers with Sb flux of 2x10⁻⁷torr and 1x10⁻⁶torr, respectively. The SQW with Sb flux of 2x10⁻⁷torr shows 3-D growth, while the SQW with Sb flux of 1x10⁻⁶torr shows 2-D growth. From TEM observations, Sb seems to react in GaInNAs/GaAs system like a surfactant, which increase the critical thickness at which the growth mode changes from the 2-D growth to the 3-D growth.

We fabricated ridge lasers with reverse mesa structure. The short cavity lasers (L=200 μ m) with high reflection (HR) coatings on both facets (R_f/R_r =78%/95%) were tested under CW operation. Figure 4 shows the temperature dependence of light-current characteristics for GaInNAsSb lasers. The low I_{th} of 12.4mA at 25°C was obtained under CW operation, which is the almost same value with the best results ever reported for narrow stripe lasers [6]. The lasing wavelength is 1.258 μ m as shown in the inset of figure 4. Large T_0 of 157K was obtained in the range of 25-85°C, and this is the best result for GaInNAs-based edge emission lasers with the low I_{th} and the large T_0 to our best knowledge [6, 7]. Further, the relatively high slope efficiency of 0.22W/A at 25°C, with the temperature dependence as small as -0.014dB/K (@25-85°C), and the CW oscillating at more than 100°C were obtained. GaInNAsSb QW lasers are very promising material for realizing pertier-free access network.

References (1)M. Kondow et al. Jpn. J. Appl. Phys., vol. 35, pp. 5711, 1996 (2)S. Sato et al. IEEE Photon. Technol. Lett., vol. 11, pp. 1560, 1999 (3)T. Kageyama et al. IEEE Photon. Technol. Lett., vol. 12, pp. 10, 2000 (4) M. Copel et al., Phys. Rev. Lett., vol. 63, pp. 632, 1989 (5) X. Yang, et al., Electron. Lett., vol. 35, pp. 1082, 1999 (6)S. Illek et al., Electron. Lett., vol. 36, pp. 725, 2000 (7)Borchet et al., Electron. Lett., vol. 35, pp. 2204, 1999

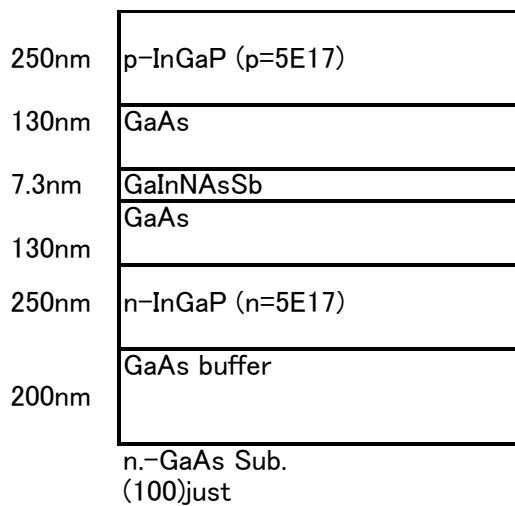


Figure 1. The schematic laser structure.

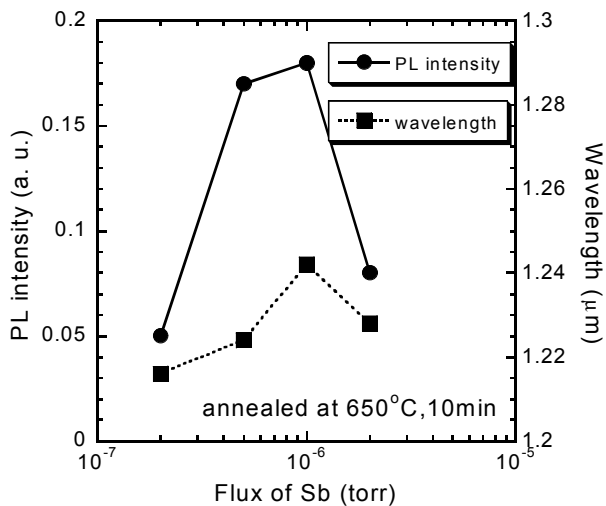


Figure 2. PL intensity and PL wavelength against Sb flux for GaInNAsSb/GaAs SQW.

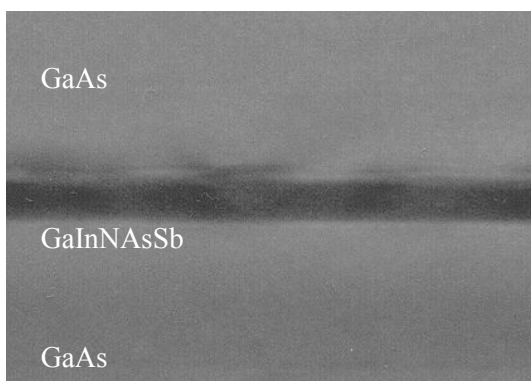


Figure 3 (a). TEM image for GaInNAsSb-SQW lasers with Sb flux of 2×10^{-7} torr

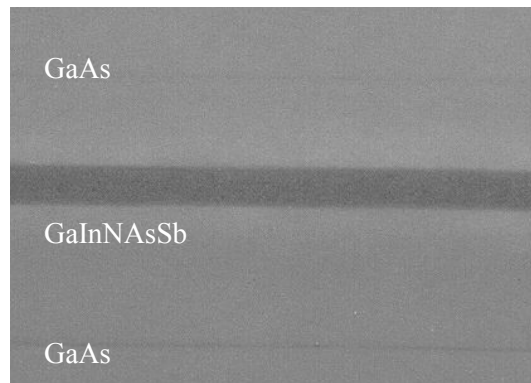


Figure 3 (b). TEM image for GaInNAsSb-SQW lasers with Sb flux of 1×10^{-6} torr.

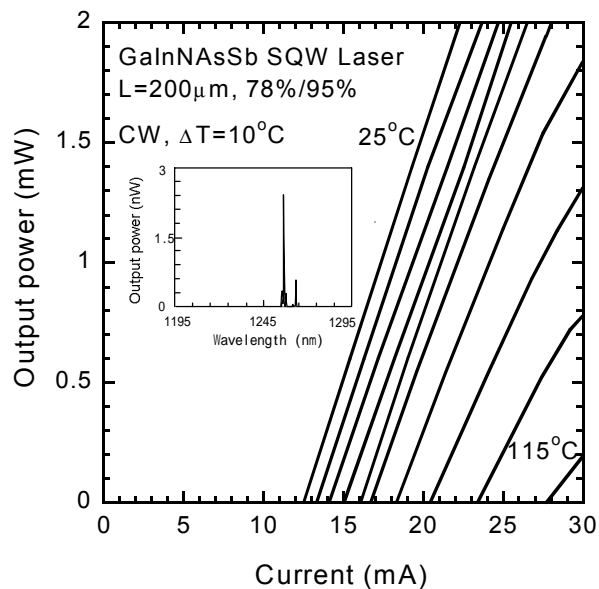


Figure 4. The temperature dependence of light-current characteristics for GaInNAsSb lasers under CW operation ($L=200\mu\text{m}$, 78%/95%). The inset shows lasing spectrum at room temperature.